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ELECTRICAL VIEWPOINT IN A COMPLETE SAFETY SURVEY OF A COAL MINE

BY

E. J. GLEIM

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By E. J. Gleim[2]

INTRODUCTION

To make a thorough survey of a coal mine in order to eliminate hazards, the competent safety engineer must be familiar with more than one branch of engineering. It is essential that he know the properties of mine gases and the methods of detecting them, as well as how to prevent dangerous gas accumulations. It is also essential that he understand the action of overlying strata when the coal is removed, and the proper methods of protection by timbering or other suitable means of support. He must know the value of protective clothing in reducing injuries and must be informed as to the correct handling and use of explosives to avoid premature blasts, misfires, and other failures in blasting practice. He must understand how to operate locomotives and cutting, loading, and various other types of machines to be able to recommend effective safeguards for protecting the men who use them. In addition to being informed as to these and many other activities connected with the mining of coal, he must not overlook electrical engineering if he wishes to combat the fire, shock, and ignition hazards attendant upon the use of electrical machinery and circuits in and around the mine intelligently. There are many points relating to safety in the selection, maintenance, and use of electrical circuits and equipment that are perfectly obvious to the electrical engineer but perhaps are not so evident to those not trained in this particular branch of engineering.

Engineers of the U.S. Bureau of Mines who have made a special laboratory study of electricity as related to safety in mines have also made inspections of electrical installations at a large number of bituminous mines. These inspections have revealed practices and conditions that not only do not contribute to safety but that add nothing to efficiency and economy in the operation of the mine.

The purpose of this paper is to state certain important rules and to discuss some of the more common violations of good practice in order that safety engineers may have some guide as to what to observe when inspecting electrical installations. Those who wish to inquire into the subject still further should consult Bureau of Mines Technical Paper 402, Safety Rules for Installing and Using Electrical Equipment in Coal Mines, published in 1926; also, the National Electrical Code. Bureau of Mines Technical Paper 537, Maintenance of Electrical Mine Equipment From the Viewpoint of the Safety Inspector, published in 1932, will also be found helpful in a detailed inspection of approved mine equipment.

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[2] Electrical engineer, U.S. Bureau of Mines, Pittsburgh Experiment Station, Pittsburgh, Pa.

The hazards associated with electricity are not confined to underground conditions. Although precautions against explosions of mine gas above ground may not have to be taken, the possibility that coal dust may ignite, with resulting fire and shock, remains to be guarded against. Moreover, failures of surface electrical equipment may seriously endanger the safety of underground workers. For example, the breakdown of a fan motor might dangerously interrupt ventilation; or an electrically initiated fire in the tipple at a shaft mine might result in smoke and flame being carried down the shaft. Accordingly, it is highly important that the surface plant be inspected if the safety survey of a mine is to be complete. For this reason, both surface and underground aspects of the electrification of a coal mine are discussed in this paper.

SURFACE INSTALLATIONS

Recognized standards as to wiring, grounding, insulation, overload protection, and other items that affect safety in most commercial electrical installations usually can be followed with equal propriety in regard to the surface installation at a coal mine. For example, the National Electrical Code, previously mentioned, which contains the regulations of the National Board of Fire Underwriters for electric wiring and apparatus, is an accepted American standard that can be followed in wiring and installing equipment in tipples, lamp houses, substations, and other buildings that comprise the surface plant at a mine. Likewise, the National Electric Safety Code, prepared by the United States Bureau of Standards, is an excellent reference for the purpose. Because such references as these are available, together with the publications previously mentioned, the scope of this paper will be limited to a consideration of those features that observation has shown to have been neglected and of those to which it is desired to draw special attention.

Transformer Stations

Although the transformers, which reduce the line voltage to that required at the mine, are usually the property of the power company, mine employees occasionally must work on or near them. But, whether the transformers are the property of the power company or of the coal company, the following safety measures should be adopted:

1. The transformers should be properly enclosed in a building or by a high fence with locked door or gate to keep away unauthorized persons.

2. Warning signs to indicate the danger from high voltage should be posted around the enclosure.

3. The transformer casings should be effectively grounded to protect against shock.

4. Insulated platforms should be provided for employees to stand on when operating high-tension switches, particularly at outdoor stations, to prevent shock.

Tipples

Often considerable wood is found to have been used in the construction of tipple buildings, particularly in the older ones. Because of the fire hazard and because of possible dust explosions, all motors, controllers, lights, and wiring must be carefully installed, protected, and maintained. The importance of these precautions is perhaps underestimated at times. The nearness of tipples to intake openings makes it imperative that no safeguard be overlooked when failure might also affect underground workers. Among the safeguards that should be considered are the following:

1. Ample fire-fighting equipment should be provided. Fire extinguishers should be inspected regularly and recharged, if necessary. They should be conveniently located and in plain view. Clothing or any other material that would obscure the extinguisher or interfere with its removal in an emergency should not be hung upon the fire extinguishers or the hooks that support them.

2. Brattice cloth is not a suitable material for keeping coal dust out of motors in the tipple. It might increase the fire hazard and retard the dissipation of heat from the motors. It would be preferable to use motors designed to exclude dust.

3. Wires between motors and their starters should not be permitted to rest on wood floors, where they can be covered with coal dust or with oil from the motor bearings. Furthermore, the wires should not be taken through cracks or holes in the floor. To minimize the risk of fire as the result of such wiring methods, it is preferable to enclose the wires in conduit. This would protect the wires from injury by tools or materials resting on them and from men walking over them.

4. Open wiring for power, lighting, and signal circuits in the tipple should be supported on insulators, so that the wires may be kept out of contact with wood and with each other. Nails bent over wires are not suitable supports. Without proper support, vibration of the tipple may ultimately cause the insulation to wear through, and when the conductors are bared, short circuits, interruptions of power, and other troubles can follow, with attendant increase of fire and shock hazards. The wires of one circuit should not support those of another. For example, a signal circuit should not be permitted to rest on a power or lighting circuit. To do so is to invite false signals and shock.

5. When open wiring is used in a tipple, it is usually wise to remove wires that are permanently out of service, so that, in case there is potential on the wires, the ends will not be free to swing where men might come in contact with them.

6. Temporary wiring frequently assumes a permanent status. For this reason, wiring should not be done carelessly in the tipple or in any other buildings of the surface plant, where it is essential that fire hazards be kept at a minimum. If the wiring cannot be placed in a grounded conduit, it should be substantially mounted on insulators or otherwise protected to prevent short circuits, open circuits, or similar electrical troubles, which are often the result of careless wiring.

7. Cases and boxes for motor starters and light and heater switches, if made of wood, should be lined carefully with fireproof material to prevent their igniting as the result of flashes and melted copper coming in contact with the wood. Metal-enclosed starters and safety switches are preferable for this purpose. Open-type switches and starters must not be used where there is danger of igniting clouds of coal dust. Switches and starters should be securely mounted so that their operation will not cause troubles arising from loose connections or broken wires.

8. If tipple wiring is not carried in a grounded-conduit system, insulating bushing should be used in all openings through which wires enter metal push-button stations, switch and starter casings. This will prevent the casings from becoming charged, as the insulation on the wires might otherwise be cut or worn through by the edges of the openings. Similarly, the ends of conduits should terminate in fittings having insulating plates or bushings in order to reduce the possibility of interruption of tipple operations because of short circuits or grounding.

9. As a precaution against shock, metal push-button stations, switch and starter casings, and motor frames should be effectively grounded unless connected to a grounded-conduit system. This means that the wire should be securely fastened against clean, bright metal of stationary parts rather than loosely hooked in some opening or twisted around the switch handle. The ground wire should be free from splices that would affect its conductivity. It should be placed where it will not be walked on or stumbled over, and it should be attached at a point where it can easily be found upon inspection. Ground wires should be inspected frequently to see that they have not been broken or corroded through.

10. Indoor types of push-button stations and switches are not suitable for outdoor service around tipples, particularly if exposed to the weather or spray from solutions, such as are used to treat domestic coal as it is loaded into trucks. Moisture and chemicals entering such control equipment can cause electrical leakage, which may result in shock to anyone touching these parts.

11. Knife-blade switches should be mounted in such a position that the blades will not close by gravity, otherwise there is danger of unintentional starting of motors, or of working on circuits that are actually energized when they are supposedly not alive.

12. When transformers are necessary in tipple operations, it is not advisable to set them on wooden shelves or surround them with boards to keep workers away from them, since the wood not only adds to the fire hazard but also affords a place for dust to accumulate and at the same time impedes air circulation past the transformers. They should be mounted outside of the tipple, especially if much wood is used in the construction of the latter, and thus oil leakage, fire, and shock hazards will be removed from the immediate neighborhood of the tipple workers.

13. Unless the lamp sockets are part of the grounded-conduit systems, weatherproof sockets should be used in the tipple, at least over picking tables and loading booms, where men would have to stand on or hold to metal parts in renewing lamps. This is necessary as a precaution against shock.

14. Drop cords for lighting in weigh rooms, control rooms, and offices in the tipple should be kept out of contact with wood or other combustibles to keep the fire hazard at a minimum.

15. Only the best grade of all-rubber insulated cord is recommended for extension lamps. In the cheaper grades the outside cotton covering quickly frays and the rubber insulation soon hardens and cracks so that the cord is easily short-circuited and the user subjected to shock. Extension lamps should not be used without fuse protection at the point of connection.

16. Covers should be kept on snap switches for lighting circuits to avoid making accidental contact with live parts; also to keep out dust.

17. Jumpers around fuse sockets and fuse clips nullify the protection that should be given lighting and other circuits in the tipple. Fuses or other suitable means of overload protection are essential in preventing overheating of wires and motors.

18. Substantial weatherproof push-button stations, or their equivalent, should be used at the dumping platform and elsewhere in the tipple for operating signal systems. Makeshift devices with bare contacts may subject the user to shock.

19. Motor-starting switches should be conveniently placed so that it will not be necessary to reach over revolving shafts or other moving parts that might catch in the clothing.

Cleaning Plants

In those cleaning plants in which air is used to assist in separating the undesirable material from the coal, coal dust is likely to be present in large quantities, both suspended in the air and settled upon the floor and other parts of the building. For this reason it is very important that every precaution be taken to guard against dust explosions. Since cleaning plants are usually of more modern construction than many tipples, the fire hazard is not so great in these plants as in tipples that are constructed largely of wood. Nevertheless, electrical equipment can ignite through accident or carelessness either in its installation or maintenance. Similarly, faulty or makeshift methods may introduce shock hazards. Consequently, many of the items considered under "Tipples" apply equally well to cleaning plants. In addition, the following should be given consideration in an inspection of these cleaning plants:

1. Lamp bulbs, particularly those that may be used in drops or extension lines for repair and inspection purposes, should be well-protected against breakage and against dust accumulating on them.

2. Motors should be of the enclosed type, preferably explosion-proof.

3. Switches, starters and controllers also should be of the enclosed type, preferably explosion-proof.

Hoist Rooms

Hoist rooms are probably not so subject to additions and alterations of the electrical installation as are some of the other buildings of the surface plant. Consequently, safety features are not so apt to be found neglected here as in other buildings where temporary or hurried changes may lead to departures from safe practice. In inspecting the hoist room, however, it would be well to check over such items given under "Tipples" as apply. In addition, the following should be considered:

1. The wiring for electrical hoist signals should be carefully protected both electrically and mechanically, to guard against failure and wrong signals.

2. Protective circuits, such as control overwind, overspeed, slack brake, etc., also should be carefully protected to prevent failure and false operation. Wires of these circuits, therefore, should not be exposed to damage by tools, moving parts, or the feet of passing men.

Substations (Generating Rooms)

Among the safeguards that should be considered, in addition to those previously mentioned, the following should be included as applying specifically to generating stations:

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1. Besides the necessity for adequate fire-fighting equipment, it is important that the proper type be available. Although sand might be suitable for extinguishing oil fires such as might occur in a circuit breaker, there are other extinguishers that are less injurious to bearings of motors and generators. The fluid used in the soda-acid type may corrode and injure windings and can also cause shock to the user if a stream is played upon live parts. Extinguishers containing carbon tetrachloride, although safe from the standpoint of shock, must be used with discretion in confined spaces on account of the poisonous gases generated. The advantages and disadvantages of other available types of extinguishers should be carefully weighed before they are selected for use around electrical equipment.

2. As a protection against shock to station operators, insulated platforms or mats should be placed in front of switchboards and around motor-generator sets.

3. Unless the station is inaccessible to unauthorized persons, contact with high-voltage apparatus back of switchboards should be prevented by the use of locked gates at the ends of the switchboards.

4. The exposed terminals of generators should be shielded to prevent conducting materials and men from touching them.

5. Surface lighting circuits should not be tapped off of transformers feeding underground power circuits of higher potentials, since grounding of one of the lines underground may put a higher potential to ground than normal on the surface circuit, and thus materially increase the shock hazard in the use of drills and lamps on the latter circuit.

6. To protect men and equipment, ground detectors should be provided for completely insulated circuits that lead underground, so that grounded lines can be located and repaired immediately.

Lamp Houses

Certain items, such as fire protection, wiring, switches, grounding, etc., listed under "Tipples" and "Substations", will be found to apply in the lamp house, where batteries for electric mine lamps are charged. In addition, there are some features that should be emphasized.

1. Insulating platforms or mats should be placed around charging racks to protect attendants and others who remove or replace batteries against shock.

2. The live parts of rheostats, switches, and other equipment for the control of charging should be carefully shielded or else enclosed to protect attendants against shock.

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Fan Houses

It is most essential that the motor and electrical equipment for driving the mine fan should be carefully installed and protected against any failures that would result in stopping the fan. Many of the precautions already mentioned in the foregoing paragraphs can be observed at the fan installation. The following are other precautions that should receive careful attention:

1. The circuit to the fan house should be independent of the tipple or any other branch circuit, so that short circuit or abnormal overloads in these branches will not stop the fan.

2. If an electric signal system is used to indicate when the fan has stopped, it should be of correct design, reliable in operation, and properly maintained so that it will neither give false signals nor fail to indicate that the fan has stopped. Cotton-covered wire is not suitable for that part of a signal circuit exposed to the weather, because false indications may be given when the cotton insulation is saturated with moisture.

3. Wires to a motor must not rest on or against metal parts, such as the motor frame, since continued vibration may eventually cause the insulation of the wires to wear through. This, in turn, may result in charging the motor frame or even in causing a short circuit that would stop the motor.

Shops

Rules for safe, reliable electrical equipment and circuits that apply in the tipple and other surface buildings also should be observed in the various shops. There are, however, some that will bear restating for the sake of emphasis, as follows:

1. Lathes and other machines having a motor or starter, or both, mounted on them should be permanently and effectively grounded. This is particularly important in order to prevent shock in the case of hand tools, such as drills and riveting machines, which may be used out of doors.

2. Indoor (house) types of receptacles, sockets, switches, and similar fittings must never be used outside for connecting drills and other tools. These types are not designed to withstand the weather and consequently fail easily, with the possibility of causing shock or burns to the user.

3. Open-type knife-blade switches are not suitable as starters for motors, particularly for such voltages as 440 A.C. and 500 D.C. On account of the shock hazard, it would be better to use enclosed safety switches. The dial type of starter, unless kept in good repair, may flash between points, and therefore it is safer to use an enclosed starter. Starters designed to return the handle to the "off" position upon voltage failure should be kept in repair, so that the handle need not be tied in the "on" position.

4. Resistors used in connection with starting appliances should be guarded to keep out both conducting and combustible material. Resistors should be mounted away from wooden walls and floors to reduce the fire hazard, unless the wood is protected by incombustible shields.

5. Solid wire is not a satisfactory substitute for fuses. Aside from the damage that may be done to wiring and equipment by the use of anything but proper overload protection, there is also the possibility that a fire may be started in the motor and wiring.

Oil Houses, Barns, Miscellaneous

1. The electrical equipment in buildings, such as oil houses and barns, where quantities of inflammable materials are likely to be stored, should receive special attention on account of the fire hazards involved. It is believed that previous paragraphs contain many suggestions that can be applied to these buildings.

2. Car hauls, truck-loading conveyors, and similar electrically driven equipment that is exposed to the weather should be carefully grounded. Likewise, switches and starters for this equipment should be enclosed and metal cases grounded, so that men standing on wet ground will not receive a shock. It is doubtful whether the tracks of railroad siding will prove effective for a grounding point.

3. Headlight wires should not be left exposed on the floor or deck of slate larries, where they can be stepped on. When headlights are permanently out of service, the wires should be disconnected as a measure of safety.

Overhead Outdoor Circuits

When electrical circuits are carried overhead from building to building, certain conditions may arise that have either a direct or indirect effect upon safety. While there are rules pertaining to industrial installations that will be found entirely suitable for a mine installation also, it will not be out of place to consider some items that occasionally are overlooked, as well as some that might be counted special.

1. Surface trolley wires should be kept at least 6-1/2 feet above the top of the rails and should be suitably guarded at all points where men regularly pass under them, unless the wires are 8 feet or more above the rails. The wires should be kept 6 inches outside of the rail. These precautions are necessary to minimize contacts of heads and carried tools with the trolley wires.

2. Telephone wires should not be wrapped around steel members of tipples or headframes for support. To guard against interruption of communication,

particularly between the surface and underground workings, it is essential that these wires be properly supported on insulators.

3. The wires in a span of a given circuit should have the same sag to keep them from swinging together. This will help to prevent short circuits that would cause power failures. A short circuit might result in a wire being burned in two and falling to the ground, with danger to men and animals.

4. High-tension lines must be carefully placed and supported so that they will not sag or fall across other lines, to avoid shock and damage to equipment if subjected to potentials above normal. This is especially important if lines to houses pass under the high-tension lines.

5. Wires of the same or different circuits, even if insulated, must not be allowed to rub against each other, as short circuits and possible damage to electrical equipment may occur when insulation fails through weathering or by friction. A short circuit between insulated wires close to wood buildings could start a fire.

6. Premature firing of explosives, ignitions of gas, and shock have occurred underground as the result of lightning discharges near mines. Such discharges can induce voltage surges, which may follow the circuits entering the mine. It is therefore important that every overhead circuit leading underground have suitable lightning protection installed as close as feasible to the point of entrance to the mine, whether it be by drift, slope, shaft, or borehole, unless the circuit is fully encased in thoroughly grounded metal conduit or armor.

UNDERGROUND INSTALLATIONS

Constantly shifting load centers and unstable roofs and floors, together with acid water and other conditions peculiar to mining, combine to make it difficult not only to make an underground electrical installation that is satisfactory initially, but also one that is hard to keep in safe order. These changing factors tend to invite methods that are slipshod or at least of a temporary character not consistent with best practice. In general, inferior materials and poor workmanship are not conducive to safety.

It has been pointed out that in the surface plant, electrical equipment should be installed and maintained with a view to eliminating or reducing the hazards of fire, shock, and explosions of coal dust. Not only are these same hazards to be considered in the underground installation; but, in addition, there may be another hazard with which to contend, namely, the presence of gas. Any electrical failure that might cause shock or ignite combustible materials must also receive consideration because it is liable to ignite explosive atmospheres. Although the coal dust in one mine may not ignite as readily as that in another, its explosibility may be enhanced by the presence of gas. Consequently, the safeguards that should be adopted to prevent explosions in one mine may not appear to be as necessary in another where conditions are different. However, in spite of this, there are certain general rules that can be followed in providing for the safety of life and property underground. The following are some that experience has shown merit consideration:

Transformer Rooms

On account of the possible fire hazard involved, the installation of transformers, especially those filled with inflammable oil, should receive particular attention. This is doubly important since the transformers ordinarily operate long periods without requiring special care.

1. Oil-filled transformers should be in a ventilated, fireproof room or vault that can be closed (preferably automatically) to isolate it from the rest of the mine if they take fire. This room should have a sill, or its equivalent, that will confine the transformer oil in case of leakage and so keep it from spreading out into the mine.

2. An oil-type circuit-breaker connected in the primary leads to the transformers should be located where it can be reached conveniently without necessitating passing the transformers. This breaker should be arranged to trip open when the doors close automatically.

Substations

Underground substations, whether of the stationary or portable type, should offer little hazard if properly installed and maintained. There are several precautions to be observed in connection with such installations, among them being the following:

1. The substation should be in a well-ventilated, fireproof room.

2. Fire protection should be adequate. Bags of rock dust and buckets of sand should not be left lying about if intended for use in fighting fires. The purpose of such material should be clearly indicated to prevent its use for something other than fire protection. Liquids that are conductors of electricity should not be used for extinguishing fires in electrical equipment because of the shock hazard. The poisonous gases evolved when carbon tetrachloride is decomposed by contact with fire make inadvisable the underground use of extinguishers containing this liquid.

3. The space in back of switchboards should be accessible from both ends, and there should be ample room around switches and other equipment back of the switchboard to provide for escape and to minimize the danger of accidental contact with live parts.

4. Ground detectors, meters, and overload protective devices on underground switchboards should be kept in proper operating condition so that full

protection may be afforded against grounded or overloaded circuits; otherwise shock and fire hazards will not be kept at a minimum.

Pump Rooms

The small gathering type of pump ordinarily does not require an elaborate installation, but since it may have to be moved from time to time, it is often installed in a careless and unsafe manner. Because pumps usually operate unattended for long periods and are not always visible to others passing by, it is especially important that workmanlike methods and suitable materials be used in their installation if they are to be reliable and safe.

Although a pump should not present many more difficulties from the electrical standpoint than any other piece of equipment that it is necessary to set up in a mine, probably more rules of good practice are violated in the selection and wiring of electrical equipment for pump rooms that will be found elsewhere underground. The following are some of the points that should be observed in making a satisfactory and safe pump installation:

1. The connection of the pump circuit to the power lines should be adequate. Wrapping the end of a conductor around a trolley hanger or feeder cable usually does not make a satisfactory connection but rather one that may heat up. Clamps that will give a firm connection should be used.

2. The wire in the pump circuit should be of proper size to carry the current. A wire that is too small may cause unnecessary reduction in voltage at the pump motor and also may overheat.

3. The negative or return wire for pump motors connected to direct-current systems should not be wrapped around wood posts or props. Wires should never be held against wood by nails clinched over them. All pump-room wiring, even if insulated, should be kept out of contact with coal, wood, and other combustible materials to reduce the hazard of fire. Furthermore, the return wire should not be left on the floor in passageways where it can be broken or stumbled over by men walking by.

4. Switches should be provided for opening the circuit to the pump and should be suitable for the purpose. A wire with a hook on the end for hanging over a trolley wire or feeder cable does not fulfill this requirement and is a shock hazard.

5. The pump-starting equipment should be of the safety type and of adequate construction and capacity for the service to be performed. For example, a single-blade open-type switch is hardly suitable as the sole means for starting a 100-horsepower pump motor. Not only is it likely to be damaged quickly, but the arcs and flashes resulting from starting and stopping the motor may also burn the one who uses it. Likewise, a hook connection such as previously mentioned is not a satisfactory starting switch. Equipment designed for 250-volt direct-current service cannot be recommended for 500-volt

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service. Double-pole knife switches made for 250 volts are liable to flash across the blades and short-circuit if attempt is made to use them for 500-volt motor starters. Starting equipment should be mounted where it will not be necessary to pass close to moving parts when starting or stopping the pump.

6. The electrical equipment for pumps should have adequate overload and short-circuit protection. If fuses are used for this purpose, they should have a capacity that is correctly proportioned to the normal current load of the motor. Pieces of copper wire are not acceptable substitutes for fuses because they are usually of such a size that they will not melt, if at all, until the current is far in excess of the amount that the motor and wires to it can safely carry without destructive heating. Enclosed-type (cartridge) fuses should be used in preference to open-link types because the spark or flash that may occur when the fuse blows is confined within the cartridge. In addition, the open link may cause grounding when used in metal switch cases, since vaporized fuse metal or parts of the fuse may come in contact with metal of the switch casing. Fuses of 250-volt rating, because of their shorter length, cannot be relied upon to protect 500-volt equipment.

For pumps connected to a grounded direct-current system, it is preferable to insert a fuse only in the positive line rather than in both positive and negative lines. The reason for this is that in the latter case a ground in the motor windings might cause the negative fuse to blow without the positive fuse also opening, unless the motor frame were effectively grounded. If the motor frame is not grounded and the negative fuse blows, it is then possible to have the frame electrically charged.

7. Resistors used as part of starting equipment should not be mounted against wood or coal unless a shield of incombustible material is placed between the resistors and the wood or coal to protect them against catching fire. Resistors should be shielded, also, to keep both conducting and inflammable materials from falling or being placed on them.

8. For protection against shock, steel switch cases and starters, also motor frames, should be effectively grounded. Although the motor may be mounted on the same bed-plate as the pump, the metal piping cannot be relied upon for grounding purposes. Rust at the joints, special acid-resisting linings, and other factors may cause the pipe to have little or no value as a grounding conductor. To be effective, the grounding wire must be firmly attached against clean metal of the motor frame, switch, and starter cases. Paint and rust act as insulators and therefore should be removed at the point of attaching the grounding wire. Furthermore, the wire should not be hung upon a switch handle or loosely inserted in bolt or rivet holes. The grounding wire should be independent of power wires, particularly with equipment for grounded direct-current systems. If the ground wire and the return are made common, the breakage of this wire would result in charging the motor frame. Grounding connections should not be concealed but rather should be visible for inspection purposes. The ground wire should be free of splices so that it will have full conductivity throughout its length.

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9. There should be insulating bushings, or their equivalent, at all openings in metal switch cases and motor frames through which wires and cables pass. Their use will materially reduce the possibility of shock by preventing contact between metal parts and live conductors when the insulation becomes worn or cut through. In time, many types of insulation lose much of their mechanical and dielectric strength and therefore, with ageing, are more easily cut through, especially if there is vibration.

10. Another strongly recommended measure of protection against shock is the use of an insulated platform to stand on when operating starters for pump motors. This platform should be stable, so that it will not tip when a man stands on it.

11. Because of the shock hazard, metal lamp sockets should not be used in pump rooms or elsewhere underground. The proper socket is of the keyless, weatherproof type, that is, without any exposed metal parts.

12. Pump motors of 100 horsepower or greater should have suitable meters connected in their circuits to indicate the amount of load.

13. Every pump that is to remain in a given place for 6 months or more should have the motor, together with its starting and control equipment, enclosed in a fireproof house or room to prevent the spread of fire that might start in the electrical apparatus.

Compressor Stations, Car Hauls, Etc.

Although the shock hazard may be somewhat greater in pump rooms than elsewhere, on account of the wet conditions usually prevailing there, it may be said that the foregoing rules are applicable to other underground installations, such as compressor stations, car hauls, rotary dumps, and other stationary motor-driven equipment.

Locomotives

In addition to the direct hazards attendant upon defective brakes and other mechanical shortcomings, the mine locomotive may contribute indirectly to underground hazards in other ways. Some of the hazards connected with the operation of locomotives may be overcome by observing the following points:

1. The locomotive should be equipped with a bell or other suitable signalling device to give warning of its approach.

2. Locomotives should not be operated without bulbs, or their equivalent, in the headlights. Proper illumination of track and roof is necessary for safe operation.

3. Lamp sockets should be mounted securely in the headlights, so that bulbs can be renewed without hazard of shock from attempting to hold a loose

socket. If sockets are not stationary with respect to the reflectors, the bulbs are liable to be broken.

4. Paper, waste, and other combustible materials should never be used to support headlight bulbs. Such materials can take fire when used in this way and might drop out unnoticed among loose coal as the locomotive proceeds.

5. Lenses should be kept in headlights to protect the bulbs and to maintain the efficiency of the reflector by excluding dirt.

6. Headlight wiring should be enclosed in conduit or otherwise protected against injury that would expose the conductors and result in short circuits or shock.

7. Auxiliary switches for control of headlights and reel motors should not have any exposed contacts that a motorman could touch accidentally and receive a shock.

Portable Equipment

Mining machines, drills, loading machines, compressors, and other types of portable equipment that may be operated at or near the face should receive special consideration if gas is liberated.

Because of its portability, both permissible and nonpermissible equipment is subjected to more severe treatment in derailments, falls of roof, and other mishaps than equipment that is not moved. Consequently, it is very important that portable equipment be kept in the best state of repair if a high degree of safety is to be assured.

Permissible equipment, that is, equipment approved by the U.S. Bureau of Mines, has been specially designed to overcome the hazard of igniting explosive atmospheres. This is accomplished by enclosing spark-producing parts in casings that will withstand internal explosions without propagating them to external explosive atmospheres. It is because of this feature that permissible equipment is recommended for use in gassy mines. Once permissible machinery is installed in a mine, it should be carefully maintained and inspected if it is to continue to afford the protection that was originally built into the machines. Maintenance of permissible equipment from the standpoint of safety has been considered in Technical Paper 537, previously mentioned.

Some of the items that should receive attention in connection with portable equipment are as follows:

1. Sometimes mine electricians make unauthorized additions to or changes in permissible equipment without the manufacturer's knowledge. Although such changes may improve the machine in some respects, they do not have the advantage of inspection and test by the Bureau of Mines. Without these, the safety of the machine may be impaired by the "improvements", and therefore the machine can no longer be said to be permissible.

2. Permissible machines should not be connected to a power source in a nonpermissible manner. For example: An approved rock-dust distributor should not be connected to a crab-reel or cable-reel locomotive, nor should it be operated as a grounded machine with return through the wheels. The combination can prove to be unsafe because of sparking at the rails.

3. Occasionally attempts are made to reconstruct so-called "flameproof" machines with the intention of using them instead of permissible machines. The use of gaskets in an effort to secure flametight joints is not a reliable substitute for the wide, accurately machined joints of the permissible machine; nor can other makeshifts be depended upon to take the place of safeguards such as strong castings, which are proved by explosion tests in the permissible machine.

4. In connecting trailing cable ends to trolley taps, no bare conductor should be left exposed outside the handle end, where it could be touched with the bare hand.

5. Pieces of trolley wire or other substitutes for proper fuses in trolley taps may deprive the cable, and possibly the machine as well, of the required protection against short circuit and overload.

6. Because trailing cables are often moved by hand, it is essential that the insulation be in good condition if shock is to be avoided. Cracked insulation and poor splicing may admit water and lead to short circuits and shock; therefore, vulcanizing of damaged insulation and of splices is recommended.

7. It is recommended that, when feasible, all portable equipment be grounded by a cable or wire separate from the power wires as a protection against shock. Grounding is a definite requirement for permissible coal drills intended to be held in the hands, because failure of insulation can easily result in charging the metal frame and handles.

Electric Heaters

Electric heaters are frequently used for their convenience in heating dispatcher's offices and electrician's and repair shops. Attention should be given to the following points in avoiding shock and fire hazards:

1. The heater should be turned on and off by means of a safety switch rather than by hooking and unhooking loose wire ends.

2. The heater circuit should be protected by fuses or their equivalent.

3. The heater should have a substantial shield to keep combustible materials from touching or falling against the heating elements.

4. If the heater is not of the portable type, it should be mounted securely in position so that it will not be moved or fall against combustible materials.

Trolley and Feeder Circuits

The proper installation and guarding of trolley and feeder circuits underground play an important part in securing protection against contact hazards as well as against fire and ignition hazards. Although roof and floor conditions often make it difficult to maintain adequate support and alinement of wires, certain well-established rules governing the position of trolley and feeder wires with respect to the rail and to the clearance side of the track, as well as those relating to sag and the spacing of hangers, should be followed as closely as possible.

The guarding of trolley and power wires to prevent shock is clearly defined in some of the State mining laws, but there are certain points that sometimes appear not to have been considered in making guards effective and complete. Various types of guards are described in Information Circular 6577, Guarding Trolley Wires in Mines.[3]

1. Wires less than 6-1/2 feet above the rail should be guarded at all points under which men are required to work and at places where they must pass under the wires. To be complete at doors, the guards must extend along the wire on both sides of the door rather than just on one side. To be complete at a pump, the guard must be on the side of the wire nearest the pump as well as on the opposite side.

2. Trolley and feeder wires should be kept out of contact with wood, coal, and other combustible materials to reduce fire hazards. This is often overlooked when wires are taken through doorways or under wooden timbers. A trolley wire in contact with a timber not only introduces a fire hazard but also is likely to cause burning of both the trolley wire and wheel as the flanges of the latter ride on the timber, and the wheel then loses positive contact with the wire.

3. The return or negative side of direct-current trolley-haulage circuits does not always receive the attention it requires, either from the standpoint of efficiency or of safety. If rail bonds are broken by derailment or become loose through vibration or rusting, the current may be diverted from its normal path through the rails and return to the generator through paths of less resistance in the earth and thus becomes "stray" current. When blasting is done by electrical means, stray currents may cause premature blasts. Electrical arcing and sparking resulting from loose and broken bonds can ignite coal resting against them. In addition to these unsafe conditions, an unsatisfactory return circuit may give rise to other dangerous conditions. High resistance in the return circuit may bring about excessive voltage drops, which, in turn, result in overheated equipment with subsequent possibilities of fire and shock because of the damage done to the equipment by continued operation on low voltage.

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[3] Gleim, E. J., Guarding Trolley Wires in Mines: Inf. Circ. 6577, Bureau of Mines, 1932, 11 pp.

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4. When two bare wires are carried along the roof for direct-current mining-machine feeder circuits, placing the positive wire next to the rib will minimize the chances of shock by contact with the positive wire, since this wire will be somewhat protected by negative wire. Bare wire circuits of this type should be carefully supported on insulators to keep the wires from touching any combustible material.

Lighting Circuits

The following items should receive attention in considering the effect of lighting circuits and the lights connected to them upon safety:

1. When lighting circuits are composed of wires smaller than the mains to which they are connected, such circuits should be protected against overload and short circuit by fuses or their equivalent, unless the protection of the main circuits furnishes adequate protection for the branch circuits connected to them. Without such protection, failure of a lighting circuit through deterioration or damage to insulation might introduce fire hazards.

2. Lighting circuits, particularly those in which a number of lamps are connected in series, should be controlled by a switch. This will enable the circuit to be opened while lamp renewals or circuit changes are being made and thus remove the possibility of shock.

3. The wires (including the return in direct-current systems) as well as the lamps themselves should be kept out of contact with wood, coal, and other combustible materials by suitable supports. For example, incandescent lamps placed inside wooden enclosures for keeping mine telephones dry should be mounted in rigid sockets to keep the lamps from touching the wood. Similarly, paper and cardboard shields, sometimes used to keep glare out of workers' eyes, should be replaced by metal reflectors, as paper may catch fire if it rests against the lamp.

CONCLUSION

As the foregoing is not intended to serve as a complete set of rules for avoiding hazards connected with electrical circuits and equipment in and around coal mines, it is probable that other precautions that should be observed will be suggested by those given.

It is plain that many hazardous conditions develop through neglect and for want of adequate maintenance. The best of safeguards may fail through accident or by deterioration as the result of long, hard service. Many of the dangerous conditions cited can be avoided by carefully following a program of regular inspection and repair; but, when safety measures have not been adopted at the outset, it becomes necessary to refer to rules and codes such as those mentioned earlier, if it is desired to provide thorough protection.

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